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(54) **INKJET HEAD AND INKJET RECORDING APPARATUS**

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(58) **Field of Classification Search**
None
See application file for complete search history.

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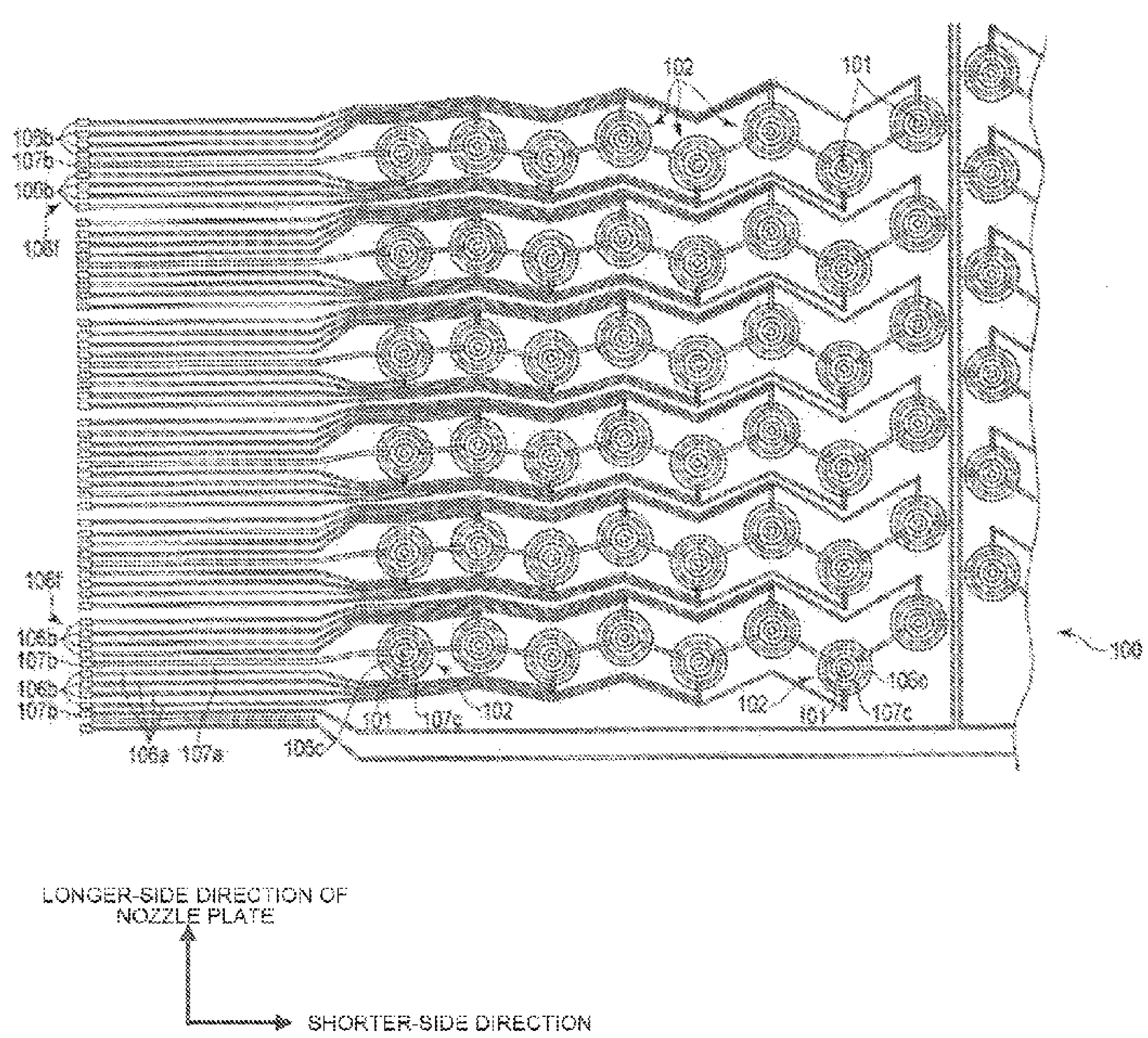
(57) **ABSTRACT**

According to an embodiment, an inkjet head includes nozzles. The nozzles are arranged on a nozzle plate. The inkjet head further includes actuators arranged corresponding to the nozzles one to one on the nozzle plate. The inkjet head further includes common electrodes and individual electrodes that apply voltage to the actuators. A connection terminal of the common electrode is arranged between connection terminals of the individual electrode.

15 Claims, 4 Drawing Sheets



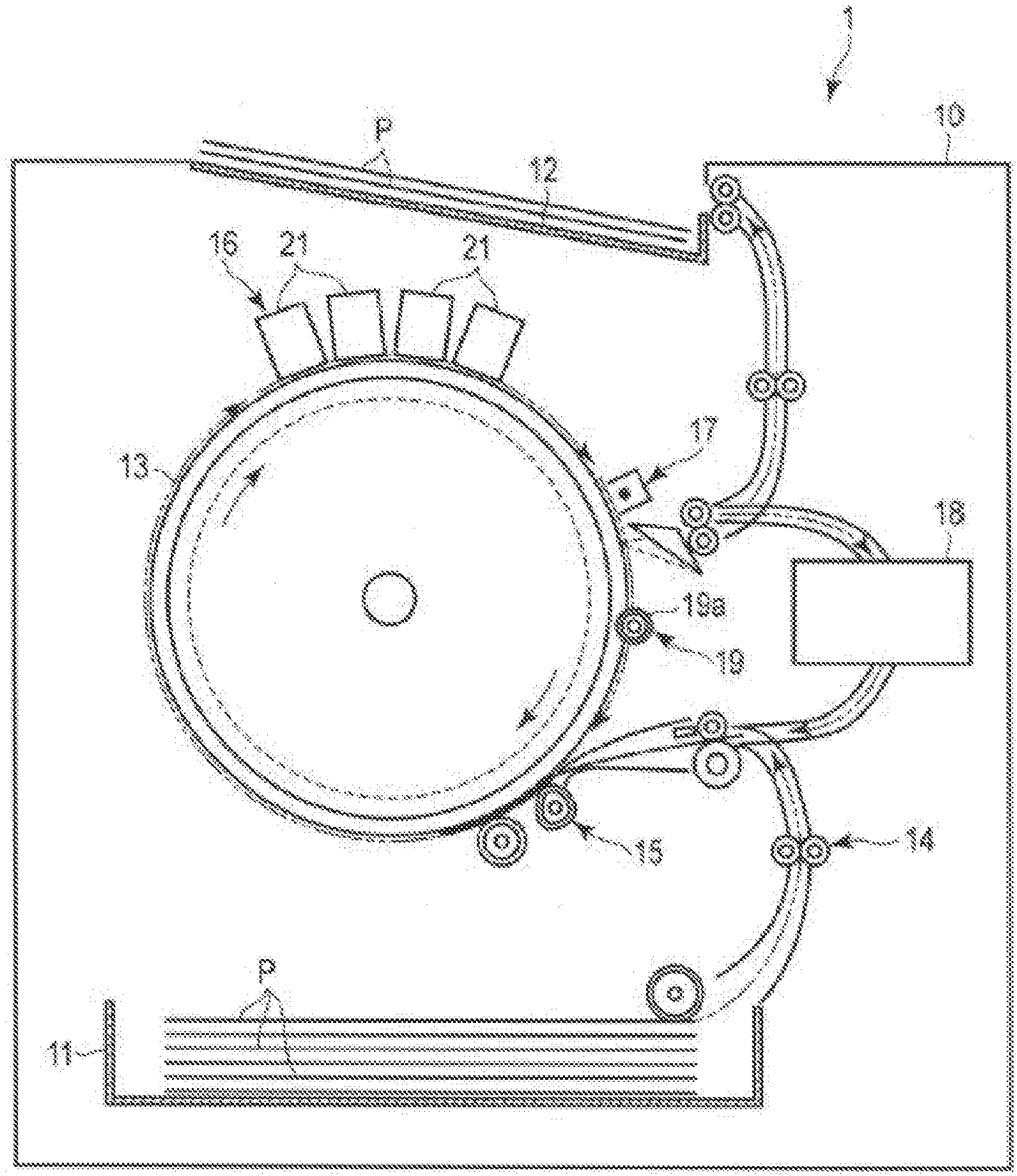
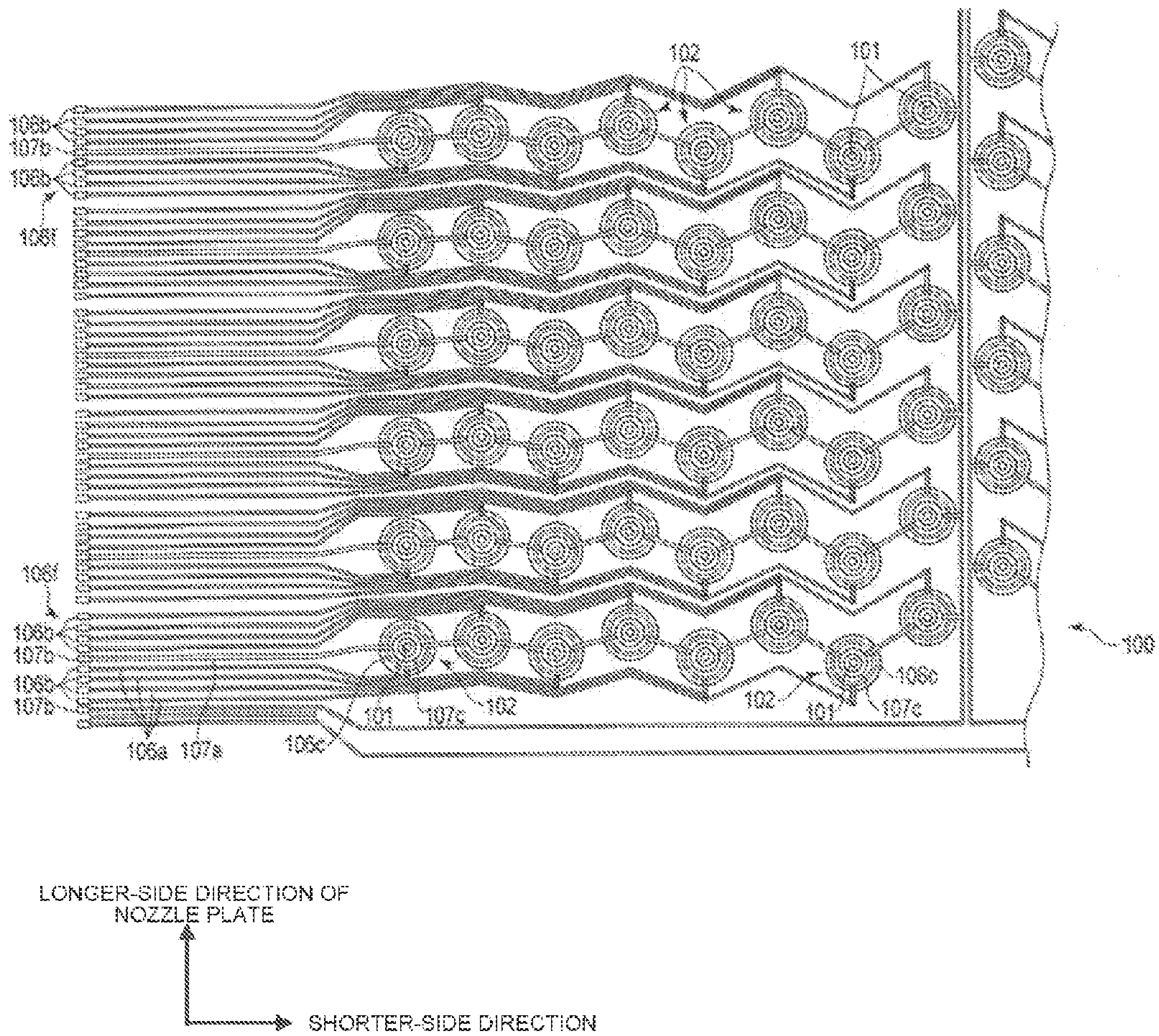


Fig.1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101
106b
107b
106b
106f
106f
106b
107b
106b
107b
106a
107a
106c
101
107c
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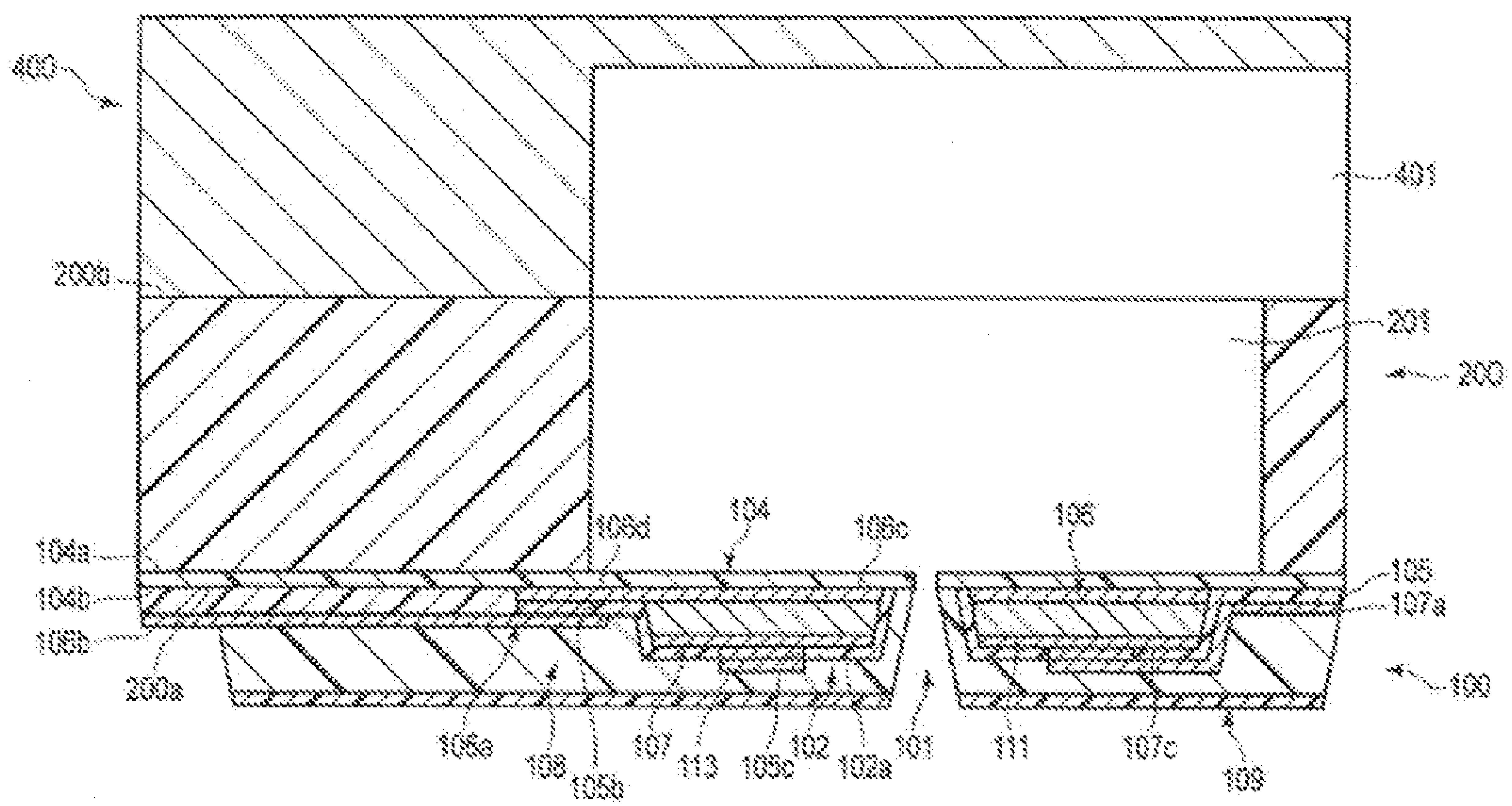
101
106c
107c
100
LONGER-SIDE DIRECTION OF
NOZZLE PLATE
SHORTER-SIDE DIRECTION

Fig.2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401
200b
201
200
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104b
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200a
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104
106c
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108
105b
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105c
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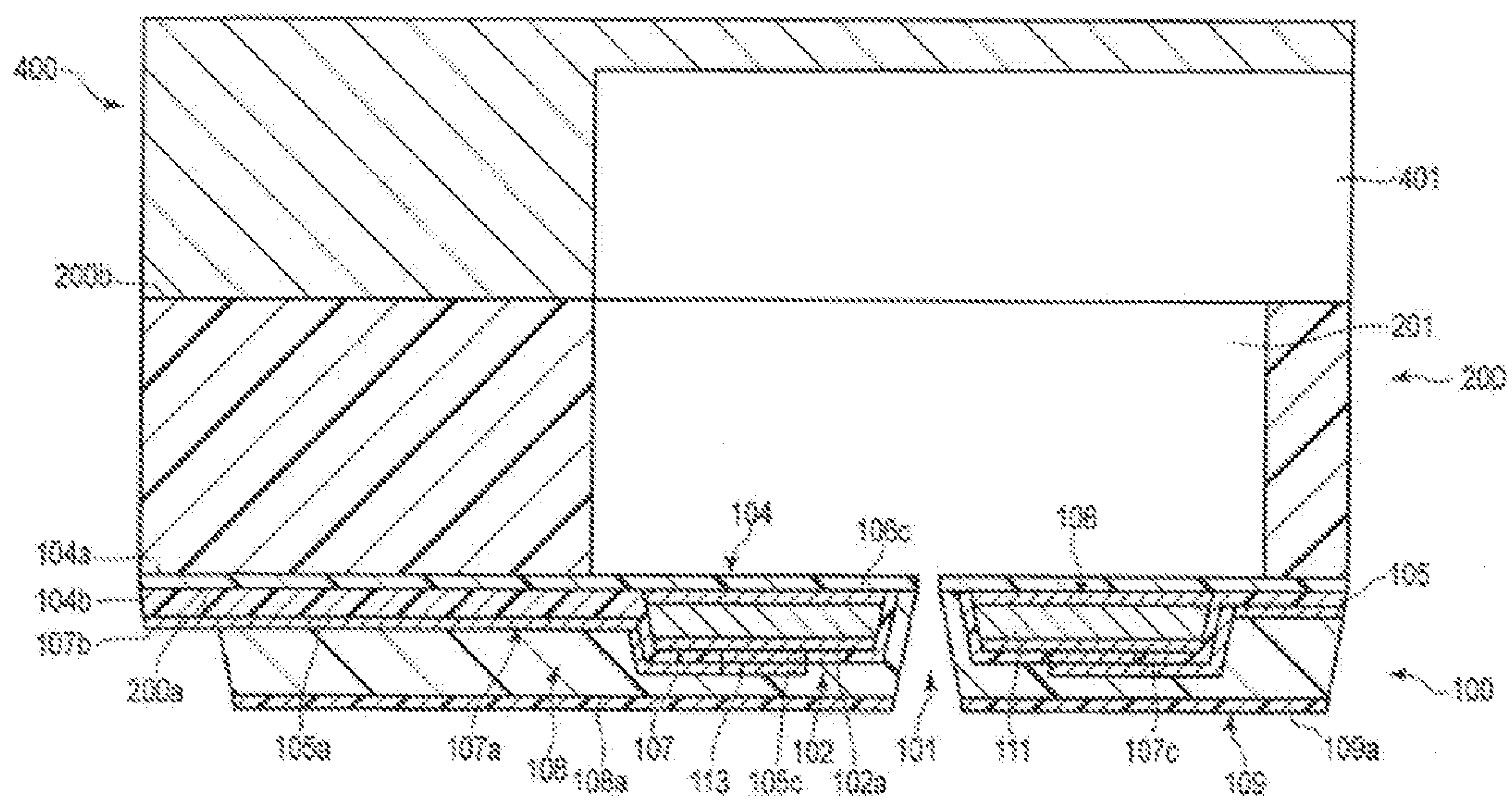
102a
101
111
107c
109

Fig.3


400
401
200b
201
200
104
106c
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104b
107b
100
200a
105a
107a
106
108a
107
113
105c
102
102a
101
111
107c
109
109a

Fig.4

INKJET HEAD AND INKJET RECORDING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2015-059703, filed on Mar. 23, 2015, the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described here generally relate to an inkjet head and an inkjet recording apparatus.

BACKGROUND

An on-demand inkjet recording system ejects ink drops from a nozzle in accordance with an image signal, and forms an image on the recording paper with the ink drops. The on-demand inkjet recording system includes those of a heating element type and a piezoelectric element type.

In the heating element type system, a heating element in ink flow paths generates air bubbles in ink. The ink drops pushed by the air bubbles are ejected from a nozzle. On the other hand, in the piezoelectric element, a piezoelectric element being an actuator deforms, and the pressure of ink stored in ink cells is thereby changed. As a result, the pressurized ink drops are ejected from the nozzle.

An example of the piezoelectric element inkjet head includes nozzles and driving elements (actuators) corresponding to each other one to one. The actuators each include a piezoelectric element, and a common electrode and an individual electrode that apply voltage to the piezoelectric element. The common electrode and the individual electrode are each electrically connected to a driving circuit via a conductor pattern. When drive voltage is applied to the piezoelectric element from the driving circuit via the common electrode and the individual electrode, the piezoelectric element deforms. As a result, the ink supplied to the pressure cell is pressurized. Part of the pressurized ink forms ink drops, and the ink drops are ejected from a nozzle.

In an inkjet head including many driving elements (actuators), if the inkjet has a structure including the common electrode described above, a connection terminal that connects the common electrode and an external terminal for applying voltage is arranged only at the end of the head body. In such a structure, the maximum distance between the connection terminal of the common electrode and the driving elements increases as the size of the head body increases. For that reason, the voltage is changed due to wiring resistance, and it may affect driving of each driving element.

In addition, if the difference between the maximum distance and the minimum distance between the connection terminal of the common electrode and the driving elements is large, the difference between voltage changes in the driving elements is large and the stability of the driving of each driving element may be reduced. Further, in the case where the connection terminal of the common electrode is arranged only at the end of the head body, current concentration occurs, and thus a problem such as short-circuiting and wiring damage may occur.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a longitudinal sectional view schematically showing the whole structure of an inkjet printer of an embodiment.

FIG. **2** is a plan view showing the structure of the main part of an inkjet head of the embodiment.

FIG. **3** is a longitudinal sectional view showing the main part of how an electrode part of an individual electrode and a connection terminal of the individual electrode in the inkjet head of the embodiment are connected to each other.

FIG. **4** is a longitudinal sectional view showing the main part of how an electrode part of a common electrode and a connection terminal of the common electrode in the inkjet head of the embodiment are connected to each other.

DETAILED DESCRIPTION

According to one embodiment, an inkjet head includes nozzles, a nozzle plate, actuators, individual electrodes, a common electrode. Each of the nozzles ejects ink. The nozzles are arranged on the nozzle plate. The actuators are arranged corresponding to the nozzles one to one on the nozzle plate. The individual electrodes are arranged on the nozzle plate, each of the individual electrodes including a connection terminal connected to an external element, each of the individual electrodes applying voltage to the corresponding actuator. The common electrode is arranged on the nozzle plate, the common electrode applying voltage to the actuators, the common electrode including a connection terminal connected to the external element, the connection terminal being arranged between the connection terminals of the individual electrodes.

Hereinafter, an embodiment will be described with reference to FIG. **1** to FIG. **4**. Note that each element, which can be expressed by some terms, may sometimes be expressed by another term or other terms. However, it does not mean that any element, which is only expressed by a single term, is never expressed by another term or other terms. In addition, it does not mean that another term or other terms, which is/are not exemplified, is/are never used to express each element. In addition, the figures show this embodiment schematically. The sizes shown in the figures may sometimes be different from those described in this embodiment. In addition, in the drawings, the same reference symbols show the same or similar parts.

FIG. **1** is a longitudinal sectional view schematically showing the whole structure of an inkjet printer **1** of an embodiment. The inkjet printer **1** is an example of an inkjet recording apparatus. Note that an inkjet recording apparatus may be another apparatus such as a copy machine instead of the inkjet printer.

As shown in FIG. **1**, the inkjet printer **1** conveys recording paper P, for example, as a recording medium, and at the same time, performs various processes such as image forming. The inkjet printer **1** includes a housing **10**, a paper cassette **11**, a copy receiving tray **12**, s holding roller (drum) **13**, a conveyer apparatus **14**, a holding apparatus **15**, an image forming apparatus **16**, a static-eliminating and peeling apparatus **17**, an inversing apparatus **18**, and a cleaning apparatus **19**.

The paper cassette **11** stores a plurality of sheets of recording paper P, and is arranged in the housing **10**. The copy receiving tray **12** is arranged at the top of the housing **10**. The inkjet printer **1** forms an image on recording paper P, and discharges the recording paper P to the copy receiving tray **12**.

The conveyer apparatus **14** includes guides and conveyer rollers arranged along the path on which the recording paper P is conveyed. The conveyer roller is driven by a motor, rotates, and thus conveys the recording paper P from the paper cassette **11** to the copy receiving tray **12**.

The holding roller **13** includes a cylindrical frame made of a conductor, and a thin insulation layer formed on the surface of the frame. The frame is grounded. The holding roller **13** rotates where it holds the recording paper P on its surface, and thus conveys the recording paper P.

The holding apparatus **15** presses the recording paper P, which is discharged from the paper cassette **11** by the conveyer apparatus **14**, on the surface (outer surface) of the holding roller **13**. The holding apparatus **15** presses the recording paper P on the holding roller **13**, and then attaches the recording paper P to the holding roller **13** by an electrostatic force of the electrostatically-charged recording paper P. The holding roller **13** holds the recording paper P where the recording paper P is attached to the holding roller **13**. The holding roller **13** rotates, and thereby conveys the held recording paper P.

The image forming apparatus **16** forms an image on the recording paper P on the outer surface of the holding roller **13**, the recording paper P being held by the holding apparatus **15**. The image forming apparatus **16** includes inkjet heads **21**, which face the surface of the holding roller **13**. The inkjet heads **21** eject four-color inks (for example, cyan, magenta, yellow, and black) toward the recording paper P, and thereby form an image on the recording paper P.

The static-eliminating and peeling apparatus **17** eliminates static electricity from the recording paper P, on which the image is formed, and thereby peels the recording paper P from the holding roller **13**. Specifically, the static-eliminating and peeling apparatus **17** electrically charges the recording paper P, and thereby eliminates static electricity from the recording paper P. Further, the static-eliminating and peeling apparatus **17** includes a peeling nail (not shown), and inserts the peeling nail between the static-eliminated recording paper P and the holding roller **13**. As a result, the recording paper P is peeled from the holding roller **13**. The conveyer apparatus **14** conveys the recording paper P, which is peeled from the holding roller **13**, to the copy receiving tray **12** or the inversing apparatus **18**.

The cleaning apparatus **19** cleans the holding roller **13** from which the recording paper P has been peeled. The cleaning apparatus **19** is arranged at the downstream of the static-eliminating and peeling apparatus **17** in the rotational direction of the holding roller **13**. The cleaning apparatus **19** includes a cleaning member **19***a*. The cleaning apparatus **19** causes the cleaning member **19***a* to come into close contact with the surface of the rotating holding roller **13**, and thereby cleans the surface of the rotating holding roller **13**.

In order to form images on the two sides of the recording paper P, the inversing apparatus **18** turns the recording paper P, which is peeled from the holding roller **13**, upside down, and supplies the recording paper P to the surface of the holding roller **13** again. Specifically, the conveyer apparatus **14** switches back the peeled recording paper P the other way around, and thereby conveys the recording paper P to the inversing apparatus **18**. The inversing apparatus **18** includes a predetermined inversion path. The inversing apparatus **18** conveys the recording paper P along the inversion path, and thereby turns the recording paper P upside down.

FIG. **2** is a plan view showing the structure of the main part of the inkjet heads **21**. FIG. **3** is a longitudinal sectional view showing the main part of how an electrode part (electrode part **106***c*) of an individual electrode (lower electrode **106**) and a connection terminal (connection terminal part **106***b*) of the individual electrode (lower electrode **106**) in the inkjet heads **21** of the embodiment are connected to each other. FIG. **4** is a longitudinal sectional view showing the main part of how an electrode part (electrode part **107***c*) of a common electrode (upper electrode **107**) and a connection terminal (connection terminal part **107***b*) of the common electrode (upper electrode **107**) in the inkjet heads **21** of the embodiment are connected to each other. Note that, for illustrative purposes, FIGS. **2**, **3** and **4** show various elements, which are actually hidden, in solid lines.

The inkjet printer **1** includes ink tanks and ink controllers (not shown), which are connected to each of the inkjet heads **21**. Each inkjet head **21** is connected to the ink tanks, which store ink of the corresponding color.

The inkjet head **21** ejects ink drops toward the recording paper P held by the holding roller **13**, and thereby forms texts and images thereon. As shown in FIGS. **3** and **4**, the inkjet head **21** includes a nozzle plate **100**, a pressure cell structure **200**, and an ink flow path structure **400**. The pressure cell structure **200** is an example of the substrate.

The nozzle plate **100** has a rectangular plate shape. The nozzle plate **100** is formed on the pressure cell structure **200**, the nozzle plate **100** and the pressure cell structure **200** being an assembly. The nozzle plate **100** includes nozzles (orifices, ink ejecting holes) **101** and driving elements (piezoelectric elements, actuators) **102**.

The nozzles **101** are circular holes. The diameter of the nozzle **101** is, for example, 20 μm. As shown in FIG. **2**, the nozzles **101** are arrayed in the longer-side direction (vertical direction of FIG. **2**) and the shorter-side direction (horizontal direction of FIG. **2**) of the nozzle plate **100**. The nozzles **101** are arranged such that the nozzles **101** in one line are spaced apart from the nozzles **101** in the next line in the longer-side direction of the nozzle plate **100**. According to this structure, the driving elements **102** are arranged in a higher density. Note that the longer-side direction of the nozzle plate **100** corresponds to the conveying direction of the recording paper P by the holding roller **13**, and the shorter-side direction of the nozzle plate **100** corresponds to the direction perpendicular to the conveying direction of the recording paper P.

The distance between the center of one nozzle **101** and the center of the next nozzle **101**, the nozzles **101** being adjacent to each other in the longer-side direction (vertical direction of FIG. **2**) of the nozzle plate **100**, is 340 μm, for example. The distance between the center of one line of the nozzles **101** and the center of the next line of the nozzles **101**, the lines being adjacent to each other in the shorter-side direction (horizontal direction of FIG. **2**) of the nozzle plate **100**, is 240 μm, for example.

The driving elements **102** are arranged corresponding to the nozzles **101** one to one. As shown in FIG. **2**, the driving element **102** and the corresponding nozzle **101** are arranged coaxially. The driving element **102** has an annular shape, and surrounds the corresponding nozzle **101**. Alternatively, the driving element **102** may have a semi-open annular shape (C shape), for example.

The pressure cell structure **200** is made of a silicon wafer, and has a rectangular plate shape. Alternatively, the pressure cell structure **200** may be another semiconductor such as a silicon carbide (SiC) substrate and a germanium substrate, for example. Alternatively, the substrate may be made of another material such as ceramics, glass, quartz, resin, and metal. Ceramics such as nitride, carbide, and oxide such as alumina ceramics, zirconia, silicon carbide, silicon nitride, and barium titanate is used. Resin such as a plastic material such as ABS (acrylonitrile butadiene styrene), polyacetal, polyamide, polycarbonate, and polyethersulfone is used. Metal such as aluminum and titanium is used. The thickness of the pressure cell structure **200** is, for example, 725 μm.

The thickness of the pressure cell structure **200** is, for example, in the range of 100 to 775 μm.

As shown in FIGS. **3** and **4**, the pressure cell structure **200** includes a first surface **200***a*, a second surface **200***b*, and pressure cells (ink cells) **201**. The first and second surfaces **200***a* and **200***b* are flat. The second surface **200***b* is opposite to the first surface **200***a*. The nozzle plate **100** is fixed to the first surface **200***a*.

The pressure cells **201** are circular holes. The diameter of the pressure cell **201** is, for example, 190 μm. Note that the shape of the pressure cell **201** is not limited to this. The pressure cell **201** penetrates through the pressure cell structure **200** in its thickness direction, and has an opening through the first surface **200***a* and an opening through the second surface **200***b*. The nozzle plate **100** covers the openings through the first surface **200***a* of the pressure cells **201**.

The pressure cells **201** are arranged corresponding to the nozzles **101** one to one. In other words, the pressure cell **201** and the corresponding nozzle **101** are arranged coaxially. According to this structure, the pressure cell **201** is in communication with the corresponding nozzle **101**. The pressure cell **201** is in communication with the outside of the inkjet head **21** via the nozzle **101**.

The ink flow path structure **400** is made of, for example, stainless steel, and has a rectangular plate shape. The thickness of the ink flow path structure **400** is, for example, 4 mm. Note that the ink flow path structure **400** may be made of any other material such as ceramics and resin. Ceramics such as nitride, carbide, and oxide such as alumina ceramics, zirconia, silicon carbide, and silicon nitride is used. Resin such as a plastic material such as ABS, polyacetal, polyamide, polycarbonate, and polyethersulfone is used. The material of the ink flow path structure **400** is selected so that the pressure is not increased to eject the ink, in consideration of the difference between the expansion coefficient of the ink flow path structure **400** and the expansion coefficient of the nozzle plate **100**.

The ink flow path structure **400** is bonded to the pressure cell structure **200** with, for example, epoxy-based adhesive. The ink flow path structure **400** includes ink flow paths **401**, an ink inlet port (not shown), and an ink outlet port (not shown).

The ink flow paths **401** are grooves on the ink flow path structure **400**. The depth of the ink flow path **401** is, for example, 2 mm. The ink inlet port is an opening at one end of the ink flow path. The ink inlet port is connected to the ink tank via a tube, for example. The ink tank is connected to the pressure cells **201** via the ink flow paths **401**.

The ink in the ink tank flows into the ink flow paths **401** through the ink inlet port. The ink supplied to the ink flow paths **401** is supplied to the pressure cells **201**. The ink filled in the pressure cells **201** flows also into the nozzles **101** via the openings of the pressure cells **201**. The inkjet printer **1** maintains the pressure of the ink at an appropriate negative level, and the ink is thereby kept in the nozzles **101**. The ink forms a meniscus on the nozzle **101**, and is kept such that the ink may not leak from the nozzle **101**.

The ink outlet port is an opening at the other end of the ink flow path **401**. The ink outlet port is connected to the ink tank via a tube, for example. The ink in the ink flow paths **401**, which has not flowed into the pressure cells **201**, is discharged to the ink tank through the ink outlet port. As described above, the ink circulates in the ink tank and the ink flow paths **401**. Because the ink circulates, the temperature of the inkjet head **21** and the temperature of the ink are kept constant, and the quality of the ink, which is affected by heat, is less changed, for example.

Next, the nozzle plate **100** will be described in detail. As shown in FIGS. **3** and **4**, the nozzle plate **100** includes the nozzles **101**, the driving elements **102**, a vibration plate **104**, an insulation film **105**, a lower electrode **106**, an upper electrode **107**, a protective film **108**, and an ink-repellent film **109**. The insulation film **105** and the protective film **108** are each an example of an insulator.

The vibration plate **104** is, for example, an SiO_2 (silicon dioxide) film formed on the first surface **200***a* of the pressure cell structure **200**, and has a rectangular plate shape. In other words, the vibration plate **104** is an oxide film of the pressure cell structure **200**, which is a silicon wafer. The vibration plate **104** may be made of another material such as single-crystal Si (silicon), Al_2O_3 (aluminum oxide), HfO_2 (hafnium oxide), ZrO_2 (zirconium oxide), and DLC (Diamond Like Carbon). The thickness of the vibration plate **104** is, for example, 4 μm. The thickness of the vibration plate **104** is in the range of 1 to 50 μm, approximately.

The vibration plate **104** includes a first surface **104***a* and a second surface **104***b*. The first surface **104***a* is fixed to the pressure cell structure **200**, and covers the pressure cell **201**. The second surface **104***b* is opposite to the first surface **104***a*.

The lower electrode **106** is formed on the second surface **104***b* of the vibration plate **104**. As shown in FIGS. **2** and **3**, the lower electrode **106** includes wiring parts **106***a* (wiring patterns), connection terminal parts **106***b*, electrode parts **106***c* that come into contact with the piezoelectric film **111**, and parallel arrangement parts **106***f*. The connection terminal parts **106***b* of the lower electrode **106** are each located at one end of the shorter-side direction of the vibration plate **104** (i.e., shorter-side direction of the nozzle plate **100**). The parallel arrangement part **106***f* includes the connection terminal parts **106***b* arranged at the end of the nozzle plate **100** in parallel. The parallel arrangement parts **106***f* are arrayed at the end of the nozzle plate **100** along the longer-side direction of the vibration plate **104** (longer-side direction of the nozzle plate **100**).

As shown in FIGS. **2** and **4**, the upper electrode **107** includes a wiring part **107***a* (wiring pattern), a connection terminal part **107***b*, and an electrode part **107***c* that comes into contact with the piezoelectric film **111**. The connection terminal part **107***b* is located at one end of the shorter-side direction of the vibration plate **104** (shorter-side direction of the nozzle plate **100**). As shown in FIG. **2**, the connection terminal part **107***b* is arranged between the connection terminal parts **106***b*. Further, the connection terminal part **107***b* is arranged at the outside part of the parallel arrangement part **106***f*. In addition, the connection terminal part **107***b* is arranged between the parallel arrangement parts **106***f* arranged along the longer-side direction of the vibration plate **104** (longer-side direction of the nozzle plate **100**). Further, the connection terminal part **107***b* is located at both ends of the parallel arrangement part **106***f*.

The lower electrode **106** is a thin film made of, for example, Pt (platinum) and Al (aluminum). The wiring part **107***a* and the connection terminal part **107***b* of the upper electrode **107** are each a thin film made of Ti (titanium) and Al. Note that the lower electrode **106** and the upper electrode **107** may be made of another material such as Ni (nickel), Cu (copper), Al (aluminum), Ag (silver) Ti (titanium), W (tungsten), Mo (molybdenum), and Au (gold).

The thickness of the lower electrode **106** and the upper electrode **107** is, for example, 0.5 μm. The film thickness of the lower electrode **106** and the upper electrode **107** is in the range of 0.01 μm to 1 μm, approximately. The width of the wiring part **106***a* of the lower electrode **106** and the wiring part **107***a* of the upper electrode **107** is, for example, 10 μm.

As shown in FIGS. **3** and **4**, the driving elements **102** each include the electrode part **106***c* that comes into contact with the piezoelectric film **111**, the piezoelectric film **111**, and the electrode part **107***c* that comes into contact with the piezoelectric film **111**. The driving element **102** is arranged on the second surface **104***b* of the vibration plate **104**. The driving element **102** applies the pressure for causing the corresponding nozzle **101** to eject ink drops to the ink in the corresponding pressure cell **201**.

The electrode part **106***c* that comes into contact with the piezoelectric film **111** of the lower electrode **106** is arranged on the second surface **104***b* of the vibration plate **104**. The electrode part **106***c* surrounds the nozzle **101** and has an annular shape. The electrode part **106***c* and the nozzle **101** are arranged coaxially. The outer diameter of the electrode part **106***c* is, for example, 133 μm. The inner diameter of the electrode part **106***c* is, for example, 30 μm. According to this structure, as shown in FIG. **3**, the electrode part **106***c* includes a part **106***d* that is arranged separately from the nozzle **101** and does not come into contact with the piezoelectric film **111**. The electrode part **106***c* comes into contact with the wiring part **106***a* at the part **106***d*, and conduction between them is thereby ensured.

The wiring part **106***a* of the lower electrode **106** connects the electrode part **106***c* and the connection terminal part **106***b* of the corresponding driving elements **102**. The wiring part **106***a* is arranged between the driving elements **102** in the shorter-side direction of the nozzle plate **100** (e.g., horizontal direction of FIG. **2**), the driving elements **102** being adjacent to each other in the longer-side direction of the nozzle plate **100** (e.g., vertical direction of FIG. **2**).

As shown in FIGS. **3** and **4**, the piezoelectric film **111** surrounds the nozzle **101**, and has the same size as the electrode part **106***c* of the lower electrode **106** and an annular shape. The piezoelectric film **111** is slightly smaller than the electrode part **106***c*. Alternatively, the piezoelectric film **111** may be larger than the electrode part **106***c*. The piezoelectric film **111** and the nozzle **101** are arranged coaxially. The piezoelectric film **111** covers the electrode part **106***c*.

The piezoelectric film **111** is a film made of lead zirconium titanate (PZT) being a piezoelectric material. Alternatively, the piezoelectric film **111** may be made of any one of various piezoelectric materials such as PTO ($PbTiO_3$: lead titanate), PMNT ($Pb(Mg_{1/3}Nb_{2/3})O_3$—$PbTiO_3$), PZNT ($Pb(Zn_{1/3}Nb_{2/3})O_3$—$PbTiO_3$), ZnO, and AlN.

The thickness of the piezoelectric film **111** is, for example, 2 μm. The thickness of the piezoelectric film **111** is determined based on its piezoelectric property, dielectric breakdown voltage, and the like. The thickness of the piezoelectric film **111** is in the range of 0.1 μm to 5 μm, approximately.

The piezoelectric film **111** is polarized in the thickness direction (e.g., vertical direction of FIG. **3**) at the time when the film is formed. In other words, for example, the piezoelectric film **111** is polarized, the side on the electrode part **106***c* being positive, the side of the piezoelectric film **111** on the electrode part **107***c* being negative. Drive voltage is applied to the electrode part **106***c* of the lower electrode **106** and the electrode part **107***c* of the upper electrode **107**. When the drive voltage is applied, the electric field in the thickness direction of the piezoelectric film **111** is applied to the polarized piezoelectric film **111**. At this time, the piezoelectric film **111** expands or contracts in the electric field direction (thickness direction of the piezoelectric film **111**), and contracts or expands in the direction (in-plane direction of the piezoelectric film **111**) perpendicular to the electric field direction, at the same time. As a result, the driving element **102**, which includes the piezoelectric film **111**, expands or contracts in the electric field direction and contracts or expands in the direction perpendicular to the electric field direction, at the same time.

As the piezoelectric film **111**, ferroelectric such as PZT is used. Note that if a strong electric field is applied to the piezoelectric film **111**, the polarization of the piezoelectric film **111** at the time when the film is formed is inverted. Because of this, the electric field in the range in which the polarization is not inverted is applied to the piezoelectric film **111**. As a result, the piezoelectric film **111** expands or contracts as described above.

The electrode part **107***c* of the upper electrode **107** surrounds the nozzle **101**, and has the same size as the electrode part **106***c* of the lower electrode **106** and the piezoelectric film **111** and an annular shape. The electrode part **107***c* is slightly smaller than the piezoelectric film **111**. Alternatively, the electrode part **107***c* may be larger than the piezoelectric film **111**. The electrode part **107***c* and the nozzle **101** are arranged coaxially. The electrode part **107***c* covers the piezoelectric film **111**. In other words, the electrode part **107***c* is provided on the ejection side of the piezoelectric film **111** (external side of the inkjet head **21**)

The piezoelectric film **111** is interposed between the electrode part **106***c* of the lower electrode **106** and the electrode part **107***c* of the upper electrode **107**. In other words, the electrode part **106***c* and the electrode part **107***c* are arranged to be overlapped on both sides of the piezoelectric film **111**. The piezoelectric film **111** insulates the electrode part **106***c* and the electrode part **107***c* from each other. The electrode part **107***c* faces the electrode part **106***c* via the piezoelectric film **111**.

The electrode part **107***c* of the upper electrode **107** constitutes the outer surface **102***a* of the driving element **102**. The outer surface **102***a* is one surface of the driving element **102** that faces the opposition side of the vibration plate **104**. In other words, the outer surface **102***a* faces the ejection side of the driving element **102**. The outer surface **102***a* is a surface approximately parallel to the second surface **104***b* of the vibration plate **104**.

The insulation film **105** covers the second surface **104***b* of the vibration plate **104**, the surface of the driving element **102**, and the wiring part **106***a* of the lower electrode **106**. The insulation film **105** includes holes **105***b* that expose the connection terminal part **106***b* of the lower electrode **106**.

The insulation film **105** is made of, for example, SiO_2. The insulation film **105** may be made of another material such as SiN (silicon nitride). The insulation film **105** has the uniform size on the second surface **104***b* of the vibration plate **104**, the surface of the driving element **102**, and the electrode part **106***c* of the lower electrode **106**. The thickness of the insulation film **105** is 1 μm. The thickness of the insulation film **105** is preferably, in the range of 0.1 μm to μm, approximately. Note that the thickness of the insulation film **105** may be partially different.

As shown in FIGS. **3** and **4**, the insulation film **105** includes contact parts **113**. Each of the contact parts **113** is a hole **105***c* provided on part of the insulation film **105** on the outer surface **102***a* of the corresponding driving element **102**. The contact part **113** has, for example, a circular shape whose diameter is 20 μm. The hole **105***b* partially exposes part of the electrode part **106***c* of the lower electrode **106**, which does not come into contact with the piezoelectric film **111**. In addition, the hole **105***c* partially exposes part of the electrode part **107***c*, which does not come into contact with the piezoelectric film **111**. The hole **105***c* is provided closer to the outer periphery of the electrode part **107***c* rather than at the center between the inner periphery and the outer periphery of the electrode part **107***c* having an annular shape.

As shown in FIG. **4**, the connection terminal part **107***b* of the upper electrode **107** and the wiring part **107***a* of the upper electrode **107** are arranged on the surface **105***a* of the insulation film **105**. In other words, the connection terminal part **107***b* and the wiring part **107***a* are arranged on the insulation film **105**. The surface **105***a* of the insulation film **105** faces the opposition direction of the vibration plate **104**.

As shown in FIGS. **3** and **4**, the wiring part **107***a* of the upper electrode **107** connects the electrode part **107***c* and the connection terminal part **107***b* of the corresponding driving element **102**. The wiring part **107***a* extends in the shorter side direction (e.g., horizontal direction of FIG. **3**) of the nozzle plate **100**.

As shown in FIG. **2**, the wiring parts **107***a* join together at near the center of the shorter-side direction (horizontal direction of FIG. **2**) of the nozzle plate **100**, and thereby forms part extending along the longer-side direction (vertical direction of FIG. **2**) of the nozzle plate **100**. As a result, the connection terminal part **107***b* and 8 electrode parts **107***c* are connected to each other by the wiring part **107***a*. On the other hand, the wiring parts **107***a*, which are connected to the driving elements **102** at the end of the shorter-side direction and pulled out to the end of the nozzle plate **100** at regular intervals, are each connected to the corresponding connection terminal part **107***b* and arranged so that the distance between the driving element **102** and the connection terminal part **107***b* decreases.

As shown in FIG. **4**, the wiring part **107***a* of the upper electrode **107** arranged on the surface **105***a* of the insulation film **105**, which covers the driving element **102**. One end of the wiring part **107***a* is connected to the electrode part **107***c* of the upper electrode **107** through the contact part **113** (hole **105***c*). In other words, the contact part **113** is obtained by partially removing the insulation film **105** in order to connect the wiring part **107***a* to the electrode part **107***c*.

The insulation film **105** separates the wiring part **107***a* of the upper electrode **107** and the electrode part **106***c* of the lower electrode **106** from each other. The insulation film **105** prevents the lower electrode **106** and the upper electrode **107** from being electrically connected.

The protective film **108** is arranged on the second surface **104***b* of the vibration plate **104**. The protective film **108** is made of photosensitive polyimide such as "Photoneece" (registered trademark) produced by Toray industries, Inc. In other words, the protective film **108** is made of an insulating material different from the insulation film **105**. Alternatively, the protective film **108** may be made of another insulating material such as resin and ceramics. Resin such as a plastic material such as another kind of polyimide, ABS, polyacetal, polyamide, polycarbonate, and polyethersulfone is used. Ceramics such as nitride, carbide, and oxide such as zirconia, silicon carbide, silicon nitride, and barium titanate is used. In addition, the protective film **108** may be made of a metal material as long as it has insulation properties for the driving element **102** and the upper electrode **107**. The metal material is, for example, aluminum, SUS, and titanium.

The material of the protective film **108** is selected in consideration of the heat resistance, insulation properties, thermal expansion coefficient, smoothness, and wettability with respect to ink. The insulation properties the material may affect the degree of change in the quality of ink when the driving elements **102** drive, in the case where the inkjet printer **1** uses ink having a high conductivity.

The protective film **108** covers the second surface **104***b* of the vibration plate **104**, the surface **105***a* of the insulation film **105**, and the wiring part **107***a* of the upper electrode **107**. In other words, the protective film **108** covers the driving element **102** and the wiring part **106***a* of the lower electrode **106** from above the insulation film **105**. The protective film **108** protects the driving element **102**, the lower electrode **106**, and the upper electrode **107** from, for example, ink and water in air. The protective film **108** includes holes exposing the connection terminal parts **106***b* and **107***b* of the lower electrodes **106** and **107**, respectively.

The Young's modulus of the material of the protective film **108** is different from the Young's modulus of the material of the vibration plate **104**. The vibration plate **104** is made of SiO_2, the Young's modulus thereof being 80.6 GPa. On the other hand, the protective film **108** is made of polyimide, the Young's modulus thereof being 4 GPa. In other words, the Young's modulus of the protective film **108** is smaller than the Young's modulus of the vibration plate **104**.

The surface **108***a* of the protective film **108** has a substantially smooth shape, but has a minute concavity and convexity. For example, part of the surface **108***a* of the protective film **108**, on which the driving element **102** is provided, protrudes than the other part. The surface **108***a* of the protective film **108** is opposite to the surface fixed to the vibration plate **104**.

The thickness of the protective film **108** is 4 μm, approximately, excluding the part of the protective film **108** on which the driving element **102**, the lower electrode **106**, and the upper electrode **107** are arranged. The film thickness of the protective film **108** is in the range of 1 to 50 μm, approximately. The thickness of the protective film **108** is the distance from the second surface **104***b* of the vibration plate **104** to the surface **108***a* of the protective film **108**. The thickness of the protective film **108** formed on the driving element **102** is 2.5 μm, approximately. This thickness of the protective film **108** is the distance from the surface **105***a* of the insulation film **105** arranged on the driving element **102** to the surface **108***a* of the protective film **108**.

The ink-repellent film **109** covers the protective film **108** and part of the insulation film **105**. The ink-repellent film **109** is made of silicon-series liquid-repellent material having liquid repellency or fluorinated organic material, such as "Cytop" (registered trademark) produced by Asahi Glass Co. Ltd. Note that the ink-repellent film **109** may be made of another material.

The ink-repellent film **109** does not cover but exposes the protective film **108** around the connection terminal part **106***b* of the lower electrode **106** and the connection terminal part **107***b* of the upper electrode **107**. The surface **109***a* of the ink-repellent film **109** constitutes the surface of the nozzle plate **100**. The surface **109***a* of the ink-repellent film **109** is opposite to the surface fixed to the protective film **108**.

The thickness of the ink-repellent film **109** is, for example, 1 μm, excluding the part of the ink-repellent film **109** on which the driving elements **102**, the upper electrode **107**, and the lower electrode **106** are arranged. The thickness of the ink-repellent film **109** is preferably, for example, in the range of 0.01 μm to 10 μm. The thickness of part of the ink-repellent film **109**, on which the driving element **102** is provided, is smaller than the other part. Note that the thickness of the ink-repellent film **109** may be constant.

Ink drops attached to the vicinity of the nozzle **101** may reduce the stability of ink ejection, the ink drops being ejected by the nozzle **101**. The ink-repellent film **109** prevents ink drops from being attached to the surface of the nozzle plate **100**.

The nozzle **101** penetrates through the vibration plate **104**, the protective film **108**, and the ink-repellent film **109**. In other words, the nozzle **101** is formed on the vibration plate **104**, the protective film **108**, and the ink-repellent film **109**. The vibration plate **104** and the protective film **108** are each ink-philic (lyophilic), and thereby the meniscus of ink stored in the pressure cells **201** is kept in the nozzle **101**. Part of the protective film **108** is interposed between the nozzle **101** and the peripheral surface of the driving element **102**.

A controller (not shown) is connected to the connection terminal part **106***b* of the lower electrode **106** via, for example, a flexible cable. The controller is, for example, an IC that controls the inkjet head **21** or a microcomputer that controls the inkjet printer **1**. On the other hand, the connection terminal part **107***b* of the upper electrode **107** is connected to, for example, GND (grounded=0V).

The controller transmits signals for driving the corresponding driving element **102** to the lower electrode **106**. The lower electrode **106** is used as an individual electrode that drives the driving elements **102** independently.

The inkjet head **21** performs printing (forms images) as follows, for example. In response to an operation from a user, a print instruction signal is input in a controller. In response to the printing instruction, the controller applies the signal to the driving elements **102**. In other words, the controller applies drive voltage to the electrode part **106***c* of the lower electrode **106**.

When the signal (drive voltage) is applied to the electrode part **106***c* of the lower electrode **106**, a difference in potential is generated between the electrode part **106***c* of the lower electrode **106** and the electrode part **107***c* of the upper electrode **107**. As a result, the electric field in the thickness direction of the piezoelectric film **111** is applied to the piezoelectric film **111**, and the piezoelectric film **111** thereby contracts. Specifically, the piezoelectric film **111** expands or contracts in its thickness direction (electric field direction), and contracts or expands in the in-plane direction (direction perpendicular to the electric field direction), at the same time. Similarly, the driving element **102** including the piezoelectric film **111** expands or contracts in the thickness direction of the piezoelectric film **111**, and contracts or expands in the in-plane direction of the piezoelectric film **111**, at the same time. In the following description, expansion and contraction of the driving element **102** (piezoelectric film **111**) only in the in-plane direction will be described, and expansion and contraction of the driving element **102** (piezoelectric film **111**) in the thickness direction will not be described.

In the nozzle plate **100**, the driving element **102** expands in the in-plane direction, and thereby deforms (bends) so that the volume of the pressure cell **201** is decreased. As a result, when the driving element **102** expands in the in-plane direction, the vibration plate **104**, which is connected to the driving element **102**, deforms (bends) so that the volume of the pressure cell **201** is decreased. In addition, the driving element **102** contracts in the in-plane direction, and thereby deforms (bends) so that the volume of the pressure cell **201** is increased. As a result, when the driving element **102** contracts in the in-plane direction, the vibration plate **104**, which is connected to the driving element **102**, bends so that the volume of the pressure cell **201** is increased. At this time, the insulation film **105** and the protective film **108** inhibits the bending of the vibration plate **104**.

In more detailed description, as shown in FIGS. **3** and **4**, the driving element **102** is sandwiched between the vibration plate **104**, the insulation film **105**, and the protective film **108**. With this structure, when the driving element **102** expands in the in-plane direction (direction perpendicular to the electric field direction) of the piezoelectric film **111**, a force is applied to the vibration plate **104**, and the vibration plate **104** deforms in concave shape in the direction toward the pressure cell **201** side. In other words, the vibration plate **104** intends to bend in the direction in which the volume of the pressure cell **201** is increased. To the contrary, a force is applied to the insulation film **105** and the protective film **108**, and the insulation film **105** and the protective film **108** deform in a convex shape in the direction toward the pressure cell **201** side. In other words, the insulation film **105** and the protective film **108** intend to bend in the direction in which the volume of the pressure cell **201** is decreased.

On the other hand, when the driving element **102** contracts in the in-plane direction (direction perpendicular to the electric field direction) of the piezoelectric film **111**, a force is applied to the vibration plate **104**, and the vibration plate **104** deforms in a convex shape in the direction toward the pressure cell **201** side. In other words, the vibration plate **104** intends to bend in the direction in which the volume of the pressure cell **201** is decreased. In addition, a force is applied to the insulation film **105** and the protective film **108**, and the insulation film **105** and the protective film **108** deform in a concave shape in the direction toward the pressure cell **201** side. In other words, the insulation film **105** and the protective film **108** intend to bend in the direction in which the volume of the pressure cell **201** is increased.

As described above, the vibration plate **104**, and the insulation film **105** and the protective film **108** intend to bend in a direction opposite to each other. Specifically, the insulator formed by the insulation film **105** and the protective film **108** generates a force (film stress) that inhibits the deforming of the vibration plate **104** by the driving element **102**.

The deformation amount of a member is affected by the Young's modulus and the thickness of the member. The Young's modulus of polyimide, which forms the protective film **108**, is smaller than the Young's modulus of SiO_2, which forms the vibration plate **104**. Because of this, when the same amount of force is applied to the protective film **108** and the vibration plate **104**, the protective film **108** deforms larger than the vibration plate **104**. Further, the insulation film **105** is thinner than the vibration plate **104**. Because of this, when the same amount of force is applied to the insulation film **105** and the vibration plate **104**, the insulation film **105** deforms larger than the vibration plate **104**.

As described above, the driving element **102** works in the bending mode (bending vibration). When voltage is applied to the driving element **102**, the vibration plate **104** deforms because of the driving element **102**, and the volume of the pressure cell **201** is thereby changed.

First, the driving element **102** causes the vibration plate **104** to deform, and the volume of the pressure cell **201** is thereby increased. As a result, negative pressure is generated on the ink stored in the pressure cell **201**, and the ink flows from the ink flow path **401** into the pressure cell **201**.

Next, the driving element **102** causes the vibration plate **104** to deform, and the volume of the pressure cell **201** is thereby decreased. As a result, the ink in the pressure cell **201** is pressurized (positive pressure is generated on the ink). The positive pressure applied to the ink does not escape to the ink flow path **401** and is kept in the pressure cell **201**. As a result, the pressurized ink is ejected from the nozzle **101**.

The larger the difference between the Young's modulus of the vibration plate **104** and the Young's modulus of the protective film **108**, the lower the voltage of the ink ejection, thereby causing the inkjet head **21** to eject ink effectively. Further, the larger the difference between the thickness of the insulator formed of the insulation film **105** and the protective film **108** and the thickness of the vibration plate **104**, the lower the voltage of the ink ejection, thereby causing the inkjet head **21** to eject ink effectively.

Next, an example of a method of manufacturing the inkjet head **21** will be described. First, before forming the pressure cells **201**, an SiO_2 film is formed as the vibration plate **104** on the entire area of the first surface **200***a* of the pressure cell structure **200** (silicon wafer). The SiO_2 film is formed by a thermally-oxidized film-forming method, for example. Note that the SiO_2 film may be formed by using another method such as a CVD method.

A silicon wafer, from which the pressure cell structure **200** is formed, is one large circular plate.

The pressure cell structures **200** are cut out from the silicon wafer later. Alternatively, one pressure cell structure **200** may be formed from one rectangular silicon wafer.

The silicon wafer is repeatedly heated and thin films are formed when the inkjet head **21** is manufactured. In view of this, the silicon wafer is heat-resistant, complies with SEMI (Semiconductor Equipment and Materials international) standard, and is mirror-polished and smoothed.

Next, a metal film as the lower electrode **106** is formed on the second surface **104***b* of the vibration plate **104**. First, Ti and Pt are sputtered, and Ti and Pt films are formed in order. The film thickness of Pt is, for example, 0.45 μm. The film thickness of Ti is, for example, 0.05 μm. Note that the metal films may be formed by another method such as vapor deposition and metal plating.

Next, the piezoelectric film **111** is formed on the metal film as the lower electrode **106**. The piezoelectric film **111** is formed by, for example, an RF magnetron sputtering method. At this time, the temperature of the silicon wafer is, for example, 350° C. After the piezoelectric film **111** is formed, the piezoelectric film **111** is heated at 650° C. for 3 hours in order to apply piezoelectricity. As a result, the piezoelectric film **111** obtains good crystallinity and good piezoelectricity, at the same time. The piezoelectric film **111** may be formed by another method such as CVD (chemical vapor deposition), a sol-gel method, an AD method (aerosol deposition method), and a hydrothermal synthesis method.

Next, a metal film of Pt as the electrode part **107***c* of the upper electrode **107** is formed on the piezoelectric film **111**. The metal film is formed by a sputtering method. The metal film may be formed by another method such as vacuum vapor deposition and metal plating.

Next, the metal film and the piezoelectric film **111** are etched, and the electrode part **107***c* of the upper electrode **107** and the piezoelectric film **111** are patterned. An etching mask is formed on the metal film, the metal film and the piezoelectric film **111** uncovered by the etching mask are etched and removed, and the electrode part **107***c* of the upper electrode **107** and the piezoelectric film **111** are thereby patterned. The metal film and the piezoelectric film **111** are patterned at the same time. Note that the metal film and the piezoelectric film **111** may be patterned individually. The etching mask is formed as follows. The metal film is coated with a photosensitive resist, then prebaked, exposed with light where it is covered with a mask on which a desired pattern is formed, developed, and postbaked.

Next, the lower electrode **106** is formed by patterning. An etching mask is formed on the piezoelectric film **111**, the electrode part **107***c* of the upper electrode **107**, and the metal film (Pt/Ti) under the piezoelectric film **111**, part of the metal film uncovered by the etching mask is etched and removed, and the lower electrode **106** is thereby patterned. The etching mask is formed as follows. The piezoelectric film **111**, the electrode part **107***c* of the upper electrode **107**, and the metal film (Pt/Ti) under the piezoelectric film **111** are coated with a photosensitive resist, then prebaked, exposed with light where it is covered with a mask on which a desired pattern is formed, developed, and postbaked.

The nozzle **101** is formed at the center of the piezoelectric film **111** and the electrode parts **106***c* and **107***c* of the lower electrode **106** and the upper electrode **107**. With this structure, a portion without the metal film and the piezoelectric film **111** is formed, the portion and the electrode parts **106***c* and **107***c* and the piezoelectric film **111** being concentric, the center of the portion and the center of the electrode parts **106***c* and **107***c* and the piezoelectric film **111** being the same. In this way, the driving element **102** is formed on the second surface **104***b* of the vibration plate **104**. By the patterning, the vibration plate **104** is exposed except for the wiring part **106***a* of the lower electrode **106**, the electrode part **106***c* of the lower electrode **106**, and the driving element **102**.

Next, the insulation film **105** is formed on the second surface **104***b* of the vibration plate **104** and the driving element **102**. The insulation film **105** is formed by the CVD method, which realizes good insulation properties at a low temperature. Alternatively, the insulation film **105** may be formed by another method such as a sputtering method and vapor deposition.

After the insulation film **105** is formed, the insulation film **105** is patterned. Because the nozzle **101** is formed, a portion without the insulation film **105** is formed, the portion and the driving element **102** being concentric, the center of the portion and the center of the driving element **102** being the same. At the same time, the contact part **113** is formed. The diameter of the portion without the insulation film **105** is, for example, 10 μm. The insulation film **105** uncovered by the etching mask is etched and removed, and the insulation film **105** is thereby patterned. The etching mask is formed as follows. The insulation film **105** is coated with a photosensitive resist, then prebaked, exposed with light where it is covered with a mask on which a desired pattern is formed, developed, fixed, and postbaked.

Next, a metal film as the wiring part **106***a* and the connection terminal parts **106***b* of the lower electrode **106** and the wiring parts **107***a* and the connection terminal part **107***b* of the upper electrode **107** is formed on the insulation film **105**. The metal film is a Ti (titanium)/Al (aluminum) thin film formed by, for example, a sputtering method. The film thickness of Ti is, for example, 0.1 μm. The film thickness of Al is, for example, 0.4 μm. The metal film may be formed by another method such as vacuum vapor deposition and metal plating. The metal film is connected to any one of the electrode part **106***c* of the lower electrode **106** and the electrode part **107***c* of the upper electrode **107** through the contact part **113**.

By patterning the metal film, the wiring part **106***a* and the connection terminal part **106***b* of the lower electrode **106** and the wiring part **107***a* and the connection terminal part **107***b* of the upper electrode **107** are formed. An etching mask is formed on the metal film, the metal film uncovered by the etching mask is etched and removed, and the metal film is thereby patterned. The etching mask is formed as follows. The metal film is coated with a photosensitive resist, then prebaked, exposed with light where it is covered with a mask on which a desired pattern is formed, developed, and postbaked.

Next, an SiO_2 film as the vibration plate **104** is patterned, and part of the nozzle **101** is formed. An etching mask is formed on the SiO_2 film, the SiO_2 film uncovered by the etching mask is etched and removed, and the SiO_2 film is thereby patterned. The etching mask is formed as follows. The vibration plate **104** is coated with a photosensitive resist, then prebaked, exposed with light where it is covered with a mask on which a desired pattern is formed, developed, and postbaked.

Next, the protective film **108** is formed on the vibration plate **104**, the insulation film **105**, the wiring part **106***a* and the connection terminal part **106***b* of the lower electrode **106**, and the wiring part **107***a* and the connection terminal part **107***b* of the upper electrode **107** by a spin coating method (spin coating). In other words, the protective film **108** that covers the insulation film **105** is formed. First, polyimide precursor-containing solution covers the second surface **104***b* of the vibration plate **104** and the insulation film **105**. Next, the silicon wafer is rotated, and the surface of the solution is thereby smoothed. The solution is baked for thermal polymerization, and removed, and the protective film **108** is thereby formed.

The protective film **108** may not be formed by spin coating. The protective film **108** may be formed by another method such as CVD, vacuum vapor deposition, and metal plating.

By patterning the protective film **108**, the nozzle **101** is formed and the connection terminal part **106***b* of the lower electrode **106** and the connection terminal part **107***b* of the upper electrode **107** are exposed. The protective film **108** is patterned in the procedure depending on the material of the protective film **108**.

The case where the protective film **108** is formed of non-photosensitive polyimide such as "Semicofine" (registered trademark) produced by Toray industries, Inc. will be described. First, polyimide precursor-containing solution is spin coated to form a film. The solution is baked for thermal polymerization, removed, and thereby burned and formed. After that, an etching mask is formed on the non-photosensitive polyimide film, part of the non-photosensitive polyimide film uncovered by the etching mask is etched and removed, and the non-photosensitive polyimide film is thereby patterned. The etching mask is formed as follows. The non-photosensitive polyimide film is coated with a photosensitive resist, then prebaked, exposed with light, where it is covered with a mask on which a desired pattern is formed, developed, and postbaked.

The case where the protective film **108** is made of photosensitive polyimide such as "Photoneece" (registered trademark) produced by Toray industries, Inc. will be described. First, solution is spin coated to form a film. After that, the solution is prebaked. After that, the solution is patterned after exposure with a mask and a developing process. In the case of positive photosensitive polyimide, portions of the mask, which correspond to the nozzle **101**, the opening (not shown), the connection terminal part **106***b* of the lower electrode **106**, and the connection terminal part **107***b* of the upper electrode **107**, are opened (light transmits through the portions). In the case of negative photosensitive polyimide, the mask shields portions of the mask, which correspond to the nozzle **101**, the opening (not shown), the connection terminal part **106***b* of the lower electrode **106**, and the connection terminal part **107***b* of the upper electrode **107**, from light. After that, the resulting object is postbaked and burned, and the protective film **108** is thereby formed.

Next, a cover tape is adhered to the protective film **108**. The cover tape is, for example, a back-side protective tape for chemical mechanical polishing (CMP) for a silicon wafer. The pressure cell structure **200** with the cover tape is turned upside down, and the pressure cells **201** are formed through the pressure cell structure **200**. The pressure cells **201** are formed by patterning.

FIGS. **3** and **4** are each a sectional view showing the inkjet head according to this embodiment, on which an insulating protective film is formed. The pressure cell structure **200** is etched by using a vertical deep dry etching dedicated to silicon substrates, which is called as Deep-RIE (see, for example, WO2003/030239), and the pressure cells **201** are thereby formed. At this time, a resist mask on which a desired pattern is formed is formed on the pressure cell structure **200** being a silicon wafer. With this structure, the pressure cells **201** are formed in a desired pattern. The resist mask is formed as follows. The pressure cell structure **200** is coated with a photosensitive resist, then prebaked, exposed with light where it is covered with a mask on which a desired pattern is formed, developed, and postbaked.

SF_6 gas is used for this etching. The SiO_2 film of the vibration plate **104** and the polyimide film of the protective film **108** are not etched when SF_6 gas is used. Because of this, the silicon wafer, which forms the pressure cells **201**, is dry etched, but the vibration plate **104** and the other members are not dry etched. In other words, the vibration plate **104** functions as an etching stop layer.

Note that instead of that etching, any one of various methods may be used such as wet etching in which chemical solution is used and dry etching in which plasma is used. The etching methods and the etching conditions may be changed depending on the material.

As described above, steps from the step of forming the driving element **102** and the nozzle **101** on the vibration plate **104** to the step of forming the pressure cells **201** in the pressure cell structure **200** are performed by using film-forming techniques, photolithography etching techniques, and a spin coating method. Because of this, the nozzle **101**, the driving element **102**, and the pressure cell **201** are formed in a silicon wafer accurately and easily.

Next, the ink flow path structure **400** is bonded to the second surface **200***b* of the pressure cell structure **200**. Specifically, the ink flow path structure **400** is bonded to the pressure cell structure **200** with epoxy-based adhesive.

Next, a cover tape is adhered to part of the protective film **108**, and the cover tape thereby covers the connection terminal part **106***b* of the lower electrode **106** and the connection terminal part **107***b* of the upper electrode **107**. The cover tape is made of resin, and the cover tape can thereby be removed from the protective film **108** easily. Thanks to the cover tape, dusts and the ink-repellent film **109** less attach to the connection terminal part **106***b* of the lower electrode **106** and the connection terminal part **107***b* of the upper electrode **107**.

Next, the ink-repellent film **109** is formed on the protective film **108**. A liquid ink-repellent film material is spin coated on the protective film **108**, and the ink-repellent film **109** is thereby formed. At this time, positive pressure air is injected into the ink inlet port. As a result, positive pressure air is discharged from the nozzle **101** in communication with the ink flow path **401**. When the liquid ink-repellent film material is coated on the protective film **108** in this situation, the ink-repellent film material less attaches to the inner wall of the nozzle **101**. After the ink-repellent film **109** is formed, the cover tape is peeled from the protective film **108**.

Next, the silicon wafer is divided, and the inkjet heads **21** are thereby formed. The inkjet head **21** is mounted in the inkjet printer **1**. A controller is connected to the connection terminal part **106***b* of the lower electrode **106** via, for example, a flexible cable. Further, the ink inlet port and the ink outlet port of the ink flow path structure **400** are connected to the ink tank via, for example, a tube.

As described above, in this embodiment, the nozzle plate **100** is formed on the pressure cell structure **200**. However, instead of forming the nozzle plate **100** on the pressure cell structure **200**, part of the pressure cell structure **200** may be used as the vibration plate **104**. For example, the driving element **102** is formed on one surface of the pressure cell structure **200**, and a hole corresponding to the pressure cell **201** is formed on the other surface of the pressure cell structure **200**. The hole does not penetrate through the pressure cell structure **200**. The forming of the hole leaves a thin layer on the one surface of the pressure cell structure **200**, and the thin layer serves as the vibration plate **104**.

Next, with reference to FIG. **2**, the operation and effect of the structure according to this embodiment will be described. The inkjet head **21** of the inkjet printer **1** of this embodiment includes the nozzle plate **100** on which the nozzles **101** are formed, and the driving elements **102** (actuators) corresponding to the individual nozzles **101** one to one. The nozzle plate **100** includes the electrode parts **107***c* (electrode parts of common electrodes), which are connected to the driving elements **102** and apply voltage to the driving elements **102**, and the electrode part **106***c* (electrode part of an individual electrode) for applying voltage to the corresponding driving element **102**. Further, the parallel arrangement parts **106***f* are provided at the end of the nozzle plate **100** (e.g., end on the left side of FIG. **2**). The parallel arrangement parts **106***f* are arranged along the longer-side direction of the vibration plate **104** (longer-side direction of the nozzle plate **100**). Each of the parallel arrangement part **106***f* includes the connection terminal parts **106***b* being the connection terminals of the individual electrodes. Each of the connection terminal parts **106***b* is connected to the electrode part **106***c* of the lower electrode **106**. The connection terminal parts **106***b* are arranged in the parallel arrangement part **106***f* along the longer-side direction of the vibration plate **104** (longer-side direction of the nozzle plate **100**). The connection terminal part **107***b* is located between the connection terminal parts **106***b*. The connection terminal part **107***b* is arranged outside of the parallel arrangement part **106***f*. The connection terminal part **107***b* is located between the parallel arrangement parts **106***f*. The connection terminal part **107***b* is located at both ends of the parallel arrangement part **106***f*. According to this structure, the connection terminal parts **107***b* of the upper electrode **107** can be pulled out to the end of the nozzle plate **100** with high frequency. As a result, the distance between the electrode part **107***c* and the connection terminal part **107***b* in the driving element **102** can be decreased as compared with the case where the connection terminal part **107***b*, which is the connection terminal of the electrode part **107***c* and the external element for applying voltage, is arranged only at the end of the head body. According to this structure, the distance between the driving element **102** and the connection terminal part **107***b* of the electrode part **107***c* can be decreased. As a result, the voltage changes caused due to wiring resistance can be reduced. Further, the difference between the maximum distance and the minimum distance between the electrode part **107***c* and the connection terminal part **107***b* in the driving element **102** can be decreased. As a result, the difference between voltage changes in the driving elements **102** is decreased, and the stability of the driving of each driving element **102** can be thereby maintained. In addition, because the connection terminal parts **107***b* are provided with high frequency, current concentration can be avoided and the reduction in yield due to short-circuiting, wiring damage, or the like, can be suppressed.

In addition, in this embodiment, the driving elements **102** (actuators) are divided into groups, and the electrode parts **106***c* of the lower electrodes **106** (individual electrodes) and the electrode part **107***c* of the upper electrode **107** (common electrode) are arranged for each group. As shown in FIG. **2**, the wiring part **107***a* of the upper electrode **107** is arranged at the substantially central position of each driving element **102** with 8 driving elements **102** as one group, herein. The wiring part **106***a* of the lower electrode **106** extends in the direction perpendicular to the direction in which the wiring parts **107***a* are arranged. Note that the wiring parts **106***a* of the lower electrode **106** are arranged at both ends of the driving elements **102** for each group in the direction in which the parallel arrangement parts **106***f* of the connection terminal part **106***b* of the lower electrode **106** are arranged. Further, the wiring parts **106***a* of the lower electrode **106** are arranged between one line of driving elements **102** and the next line of driving elements **102**, the lines being adjacent to each other in the longer-side direction of the nozzle plate **100**, and is pulled out to the connection terminal parts **106***b*. According to this structure, the driving elements **102** in each group can be regularly formed to have the same shape, and the method of manufacturing the inkjet heads **21** can be made easy.

Note that the number of driving elements **102** in one group does not necessarily need to be the same and the number of driving elements in each group may be changed although the example in which all of the groups have the same number of driving elements **102** with 8 driving elements **102** as one group has been described in this embodiment. Also in this case, the difference between the maximum distance and the minimum distance between the electrode part **107***c* and the connection terminal part **107***b* in the driving element **102** can be decreased. As a result, by forming the connection terminal parts **107***b* of the electrode part **107***c* with high frequency, the maximum distance between the connection terminal parts **107***b* of the electrode part **107***c* and the driving elements **102** can be decreased and the difference between the maximum distance and the minimum distance can be reduced, at the same time. The driving element **102** is thereby less affected.

According to this embodiment, it is possible to decrease the maximum distance between the connection terminal of the common electrode and the driving element (actuator), and to provide an inkjet head and an inkjet recording apparatus having high stability obtained by driving each driving element stably.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. An inkjet head, comprising:

a nozzle plate with a plurality of nozzles for ejecting ink;

actuators arranged on the nozzle plate, the actuators corresponding to the nozzles one to one;

individual electrodes on the nozzle plate, each of the individual electrodes being electrically connected to a corresponding one of the actuators and including a connection terminal connectable to an external element; and

a common electrode on the nozzle plate and electrically connected to each of the actuators, the common electrode including a wiring, which connects adjacent actuators, and a connection terminal connectable to the external element, the connection terminal of the common electrode being between the connection terminals of the individual electrodes.

2. The inkjet head according to claim **1**, wherein

the actuators are divided into groups,

the individual electrodes and the common electrode are provided for each of the groups, and

a parallel arrangement part is provided at an end of the nozzle plate for each of the groups, the parallel arrangement part including the connection terminals of the individual electrodes arranged in parallel with each other.

3. The inkjet head according to claim **2**, wherein

the connection terminal of the common electrode is provided outside of the parallel arrangement part.

4. The inkjet head according to claim **3**, wherein

each of the individual electrodes includes

an electrode part connected to the corresponding actuator, and

a wiring part that connects the connection terminal of the individual electrode and the electrode part to each other, and

the wiring part is arranged between the actuators and is pulled out to the connection terminal of the individual electrode.

5. The inkjet head according to claim **2**, wherein

each of the groups has a same number of individual electrodes.

6. The inkjet head according to claim **4**, wherein

the wiring parts of the individual electrodes for one group of the actuators are provided at both the sides of the one group of the actuators in an arrangement direction, the connection terminals of the individual electrodes being arranged in the parallel arrangement part in the arrangement direction.

7. An inkjet recording apparatus, comprising:

a conveyer apparatus that conveys recording paper; and

an inkjet head that ejects ink on the recording paper conveyed by the conveyer apparatus to form an image, wherein

the inkjet head includes:

a nozzle plate with a plurality of nozzles for ejecting ink,

a plurality of actuators arranged on the nozzle plate, the actuators corresponding to the nozzles one to one,

individual electrodes on the nozzle plate, each of the individual electrodes being connected to a corresponding one of the actuators in the plurality of actuators and including a connection terminal connectable to an external element, and

a common electrode on the nozzle plate and connected to the plurality of actuators, the common electrode including a wiring, which connects adjacent actuators in the plurality, and a connection terminal connectable to the external element, the connection terminal of the common electrode being between the connection terminals of the individual electrodes.

8. The inkjet recording apparatus according to claim **7**, wherein

the actuators are divided into groups,

the individual electrodes and the common electrode are provided for each of the groups, and

a parallel arrangement part is provided at an end of the nozzle plate for each of the groups, the parallel arrangement part including the connection terminals of the individual electrodes arranged in parallel with each other.

9. The inkjet recording apparatus according to claim **8**, wherein

the connection terminal of the common electrode is provided outside of the parallel arrangement part.

10. The inkjet recording apparatus according to claim **9**, wherein

each of the individual electrodes includes

an electrode part connected to the corresponding actuator, and

a wiring part that connects the connection terminal of the individual electrode and the electrode part to each other, and

the wiring part is arranged between the actuators and extends to the connection terminal of the individual electrode.

11. An inkjet head, comprising:

a plurality of nozzles configured to eject ink;

a nozzle plate having the plurality of nozzles arranged in a first direction and in a second direction perpendicular to the first direction;

actuators arranged on the nozzle plate to correspond with each of the nozzles, the actuators including first actuators which are arrayed in the first direction and second actuators which are arranged next to the first actuators in the second direction and are arrayed in the first direction;

a plurality of first individual electrodes arranged on the nozzle plate and configured to apply voltage to each of the first actuators, each of the first individual electrodes including a first connection terminal connectable to an external element;

a plurality of second individual electrodes arranged on the nozzle plate and configured to apply voltage to each of the second actuators, each of the second individual electrodes including a second connection terminal connectable to the external element;

a first common electrode arranged on the nozzle plate and configured to apply voltage to the first actuators, the first common electrode including a wiring which connects two adjacent actuators of the first actuators and a third connection terminal which is arranged next to the first connection terminal and is connectable to the external element; and

a second common electrode arranged on the nozzle plate and configured to apply voltage to the second actuators, the second common electrode including a wiring which connects two adjacent actuators of the second actuators and a fourth connection terminal which is arranged next to the second connection terminal and is connectable to the external element.

12. The inkjet head according to claim **11**, wherein

the first common electrode connects two adjacent actuators of the first actuators in a shortest distance, and the second common electrode connects two adjacent actuators of the second actuators in a shortest distance.

13. The inkjet head according to claim **12**, wherein

the first connection terminals and the second connection terminals are provided on an end portion of the nozzle plate located in the first direction relative to the individual electrodes.

14. The inkjet head according to claim **13**, wherein

the first connection terminals are located on opposite sides of the third connection terminal in the second direction, and

the second connection terminals are located on opposite sides of the fourth connection terminal in the second direction.

15. The inkjet head according to claim **14**, further comprising

a third common electrode arranged on an end area of the nozzle plate in the second direction relative to the nozzles, the third common electrode including a fifth connection terminal, which is connectable to the external element, and connecting to the first common electrode and the second common electrode.

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